# BEARING CAPACITY OF PARTIALLY SKIRTED FOOTINGS ON SAND

To fulfil the requirements of achieving S-1 Graduate Degree
of Civil Engineering Department of Engineering Faculty

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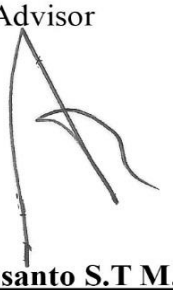

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# BEARING CAPACITY OF PARTIALLY SKIRTED FOOTINGS ON SAND


## Abstrak

Daya dukung tanah memiliki faktor yang sangat penting dalam menentukan tiper pondasi. Penting untuk menemukan cara untuk meningkatkan dari kedua sektor dasar baik itu pada pondasi atau pada tanah. Dengan menambahkan *skirt* sebagian (penahan vertikal sebagian) mengelilingi permukaan pondasi dapat digunakan sebagai salah satu alternatif dalam meningkatkan daya dukung pondasi. Penelitian ini menggunakan duabelas model laboratorium *skirt* sebagian dengan berbagai macam ukuran diameter dan panjang *skirt* sebagian, dengan pemadatan yang sama pada tanah pasir sebagai media. Dari hasil percoban didapatkan *skirt* sebagian meningkatkan daya dukung pondasi hingga 2,97 kali dari pondasi tanpa *skirt*. *Skirt* sebagian juga mengurangi penurunan yang terjadi hingga 82% pada nilai beban yang sama yaitu 2kN. *Skirt* sebagian yang memiliki *skirt* terpanjang menghasilkan pengurangan penurunan yang terbaik.



**Kata Kunci:** ***skirt sebagian, pondasi melingkar, daya dukung, penurunan, pondasi, pasir.***



## Abstract

Soil bearing capacity has the most important role to determine the type of foundation. It is important to find an effort of improvement in both sectors of fundamental area either it is on foundation or in soil itself. By adding the partially skirt (partially vertical plate) surroundings under the footings surface can be used as an alternative of improvement the bearing capacity of foundation. This research is performing twelve laboratory models of partially skirted footings with different diameter and partially skrit length, on the sand soil as a media with same compaction method. From the laboratory test which has been done, it was found that the partially skirts improve the bearing capacity of foundation up to 2.97 times than the unskirted foundation. The partially skirt also reduce the settlement up to 82 % in average in the same value of 2 kN load. The partially skirt with the longest skirt has the best result in reducing the settlement.



**Keywords:** ***partially skirt, circular footing, bearing capacity, settlement, foundation, sand.***


## 1. INTRODUCTION

Foundation is the part of the building that is located under the soil surface which continous the load of the building to the earth. In the civil engineering

world, there are two types of foundation that is commonly used in the structure of a building, those are shallow foundation and deep foundation. Shallow foundation usually used in the type of soil with good bearing capacity at the surface of the soil, the main idea of shallow foundation is to carry the load directly. The example of shallow foundations are spread footings, continous footings and raft footings. Deep foundation is defined as a foundation that carry the load of a building through the hard soil level because the bearing capacity of the soil at the surface is low or not safety enough to carry the load. The deep foundation has two types, e.g. pier foundation and pile foundation.

Soil bearing capacity has the most important role to determine the type of foundation. The bearing capacity means that the strength of soil to carry the load above them or in other words the bearing capacity refers on shear strength of soil against the settlement.

A strong and good foundation is a key of every structural design. To support the building's load and the soil movement needs a perfect calculation to make the foundation does not collapse. In shallow foundation that is commonly used in type of soil with good bearing capacity at the surface of the soil, it is important to know the limit of the shallow foundation and how to improve the strength of it.
By these explanation, it is important to find an effort of improvement in both sectors of fundamental area either it is on foundation or in soil itself. This research will be focused on the improvement of the cirucular footings. By adding the partially skirt (partially vertical plate) surroundings under the footings surface. This type of footings is known as partially-skirted footings. The hallmarks of the partially-skirted footings are less of volume and assembly costs cheaper than the conventional skirted footings.

Bucket foundation or skirt foundation is one of the shallow footings type with speciality in improvement of the soil bearing capacity. El Wakil (2013) from Alexandria University has already tested the function of skirt foundation in order to improve the bearing capacity value of shallow footings.

## 2. METHOD

To do the experiment about behavior of partially skirted footings, laboratory test were conducted on a small scale model. Nine partially skirted circular footings models. The skirts have thickness ($T_s$) of 2 mm for 75, 100, 150 mm external diameter, and 75, 100, 150 mm length for each diameter. The footings itself have 10 mm thickness ($T_f$) and also it have the same diameters with skirt's external diameter. So, the ratio of skirt length (L) to footings diameter (D), L/D are 0.50, 0.67, 0.75, 1.00 (75/75), 1.00 (100/100), 1.00 (150/150), 1.33, 1.5, and 2.00, with the gap of partially skirt footings is 3 mm. Three partially unskirted circular footings models, with 75, 100, 150 mm diameter and 10 mm thickness. L/D is 0.00. The partially skirts are wrapped well and accurately attached to periphery of the footings. All the models of footings have a notch at the top center for the placement of piston so the load straight to the middle of circular footing. Two holes are drilled at the side of the notch to observe the surface of sand inside the partially skirts. The sand sample is coming from Klaten District, Central Java Province, Indonesia.

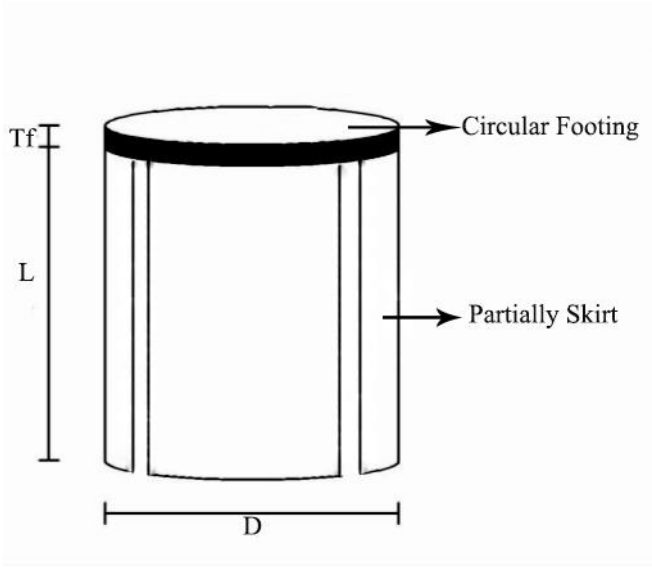


Figure 1. Partially skirted circular footings model

where,

L : length of partially skirt; 75 mm, 100 mm, 150 mm.

$T_f$ : thickness of footings; 10 mm.

D : diameter of partially skirt & circular footings; 75 mm, 100 mm, 150 mm.

Soil bin. It is made of a cylinder container with 500 mm height and 600 mm diameter, the top side circle is opened. Hydraulic loading machine. Frame Load Testing machine, to measured the load with the maximum load is 250 kN, with two-dial gauges used to measure the footings vertical displacements. The piston is placed right above the notch of footings.

The compaction used a hammer, the hammer that is used for the Standard Compaction Test with 5.5 lbs (2.5 kg) weight and 12 inch (305 mm) free fall height.

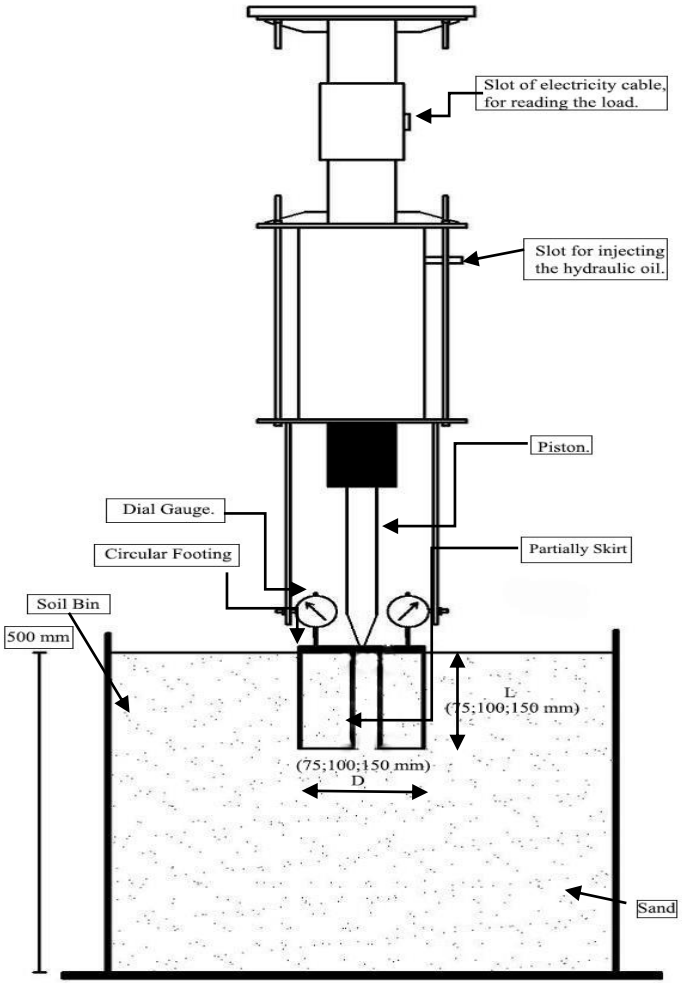


Figure 2. Sketch setup of testing procedures

First step, it is preparing and setting up the hydraulic loading mechine and the material of sand soil that will be used for the research. Sand should be taken from a certain same location and same condition. Sand should be dried on the room

temperature (27-30°C) before it is used to the investigate the water content. Next, the sand is already dry (on room temperature), and then investigating the value of air-dried water content. Second step, it is time for conducting the laboratory test of the effect of partially skirted footings toward the settlement of sand soil. *First*, the sand which is already known the value of air-dried water content is added by 1000 ml water on the 20 kg of sand, mix it well untill the water is absorbed into the sand soil . *Second*, compact the sand inside the soil bin layer by layer, for the 9 layers, every layer is 20 kg of sand, and it is compacted 100 times free fall hammer hit for each layer. *Third*, setting the soil bin and compacted sand under the loading test machine. *Fourth*, for the first test, placing the circular footings that has L/D = 0.5 right on centre of soil bin, and press the partially skirted footings until the surface of it levels with the surface of sand soil as the media, observe the surface of sand inside the partially skirt through out two open holes on the footings. *Fifth*, setting the two dial gauges on the left and right side of footings to shows how much the settlement of the partially skirted footing is and dials should touch the surface of footings. Then, also setting the piston straight up the notch of the footings and the piston should be contacted with the notch. Sixth, running the hydraulic loading test machine, observing and recording all of the data by the change of the dials and from the digital device of loading. The settlement's value will be shown by the dials gauge. While the load value given will be read by the digital device of loading. *Last*, stop the test when the load number indicated by tools decreases, as the indication that the foundation has been collapse. The test sequence will be the same for the rest of the partially skirted footings, L/D = 0.67, 0.75, 1.00 (75/75), 1.00 (100/100), 1.00 (150/150), 1.33, 1.5, and 2.00. The comparasion data of partially skirted footings and unskirted footings obtained from the result of test both catagories. A series of tests for unskrited footings sequance performed the same as the partially skirted footings (Step II), but it just replaces the partially skirted footings with the unskirted footings, diameter 75, 100, and 150 mm.

## 3. RESULT AND DISCUSSION

The test of the partially skirted and unskirted footingss has to be conducted with the same amount of water added and the same method of compaction. The air-dried water content of the sand soil is 9.41%. The compaction method for the test is using standard hammer from Standard Compaction Test with 100 times free fall height for each layer. The amount of water added is 1000 ml for each layer. . The relationship between the load and the settlement that occur on every footings. The relationship are shown on Figure 1-3.

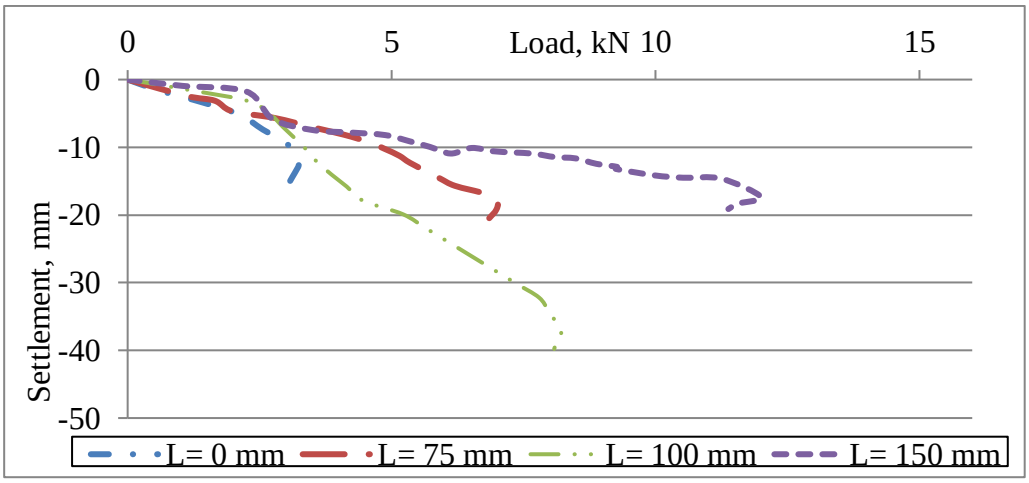


Figure 3. Load-settlement relationship for footings 75 mm diameter.

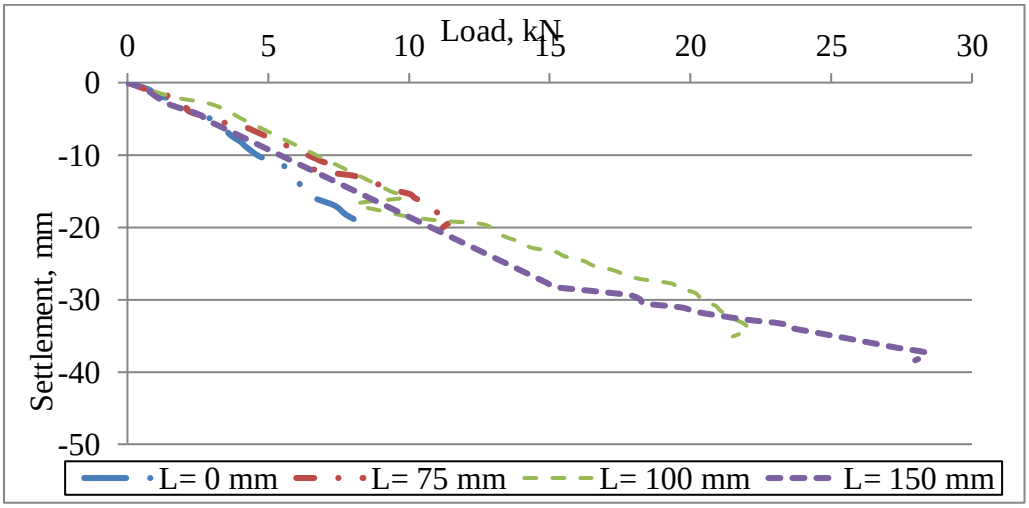


Figure 4. Load-settlement relationship for footings 100 mm diameter.

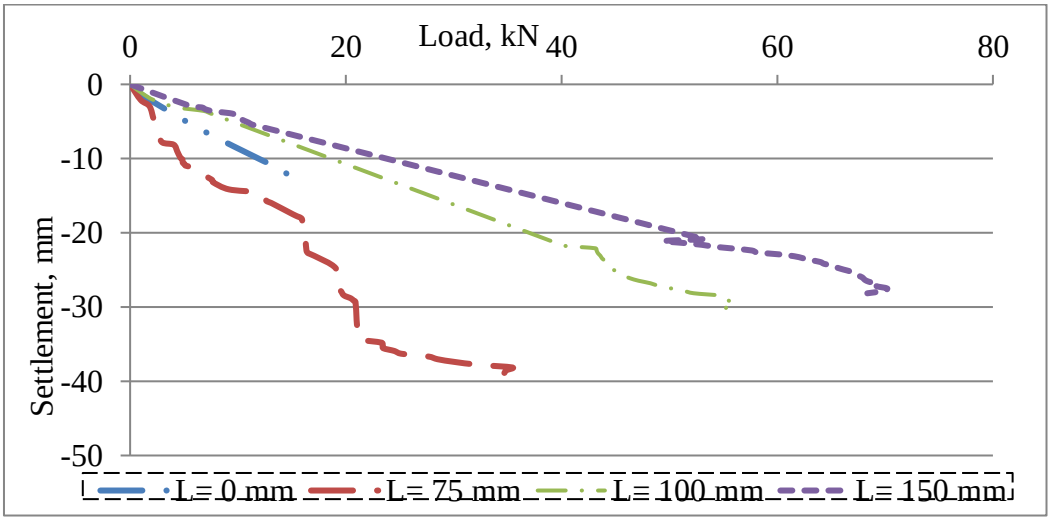


Figure 5. Load-settlement relationship for footings 150 mm diameter.

### 3.1 Ultimate Bearing Capacity

Based on the test result and investigation of 9 models partially skirted footings and 3 models unskirted footings, the result shows that maximum load of partially skirts's pattern will increase in every type of diameter as long as the comparison L/D shows the bigger value. It indicates that the ultimate bearing capacity also ascend as well.

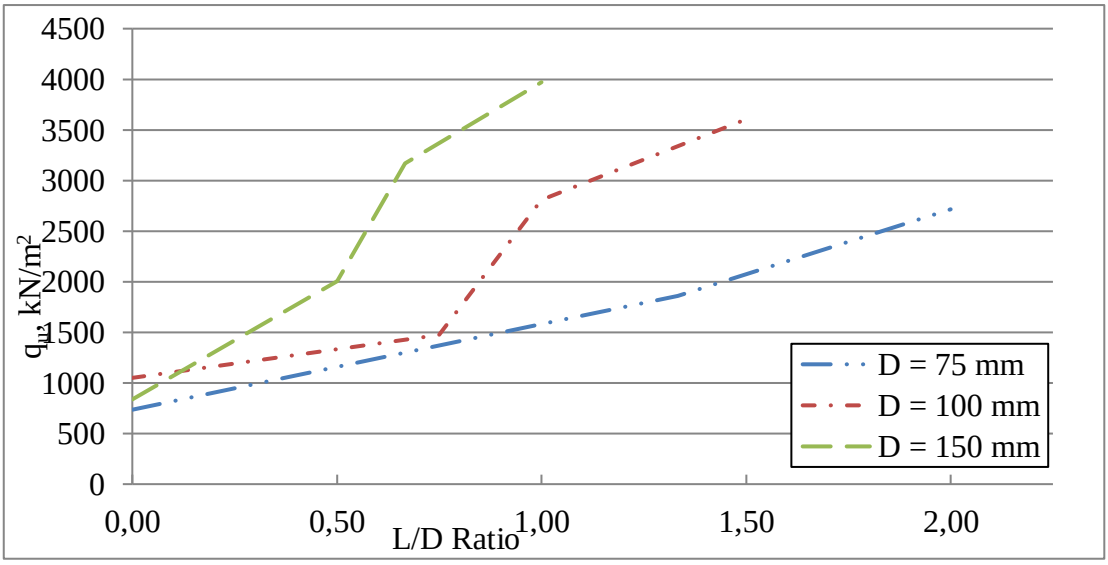


Figure 6. Ultimate bearing capacity, L/D ratio relationship, different L.

Table 1. Ultimate bearing capacity on different partilally skirt length.

| Footings Diameter D (mm) | Area, A ($mm^2$) | Partially Skirt Length, L (mm) | Length/Diameter | Max. Load, $P_{max}$ (kN) | Ultimate Bearing Capacity, $q_u$ ($kN/m^2$) |
|---|---|---|---|---|---|
| 75 | 4419.64 | 0 | 0.00 | 3.25 | 735.35 |
| 75 | 4419.64 | 75 | 1.00 | 7.00 | 1583.84 |
| 75 | 4419.64 | 100 | 1.33 | 8.21 | 1857.62 |
| 75 | 4419.64 | 150 | 2.00 | 12.00 | 2715.15 |
| 100 | 7857.14 | 0 | 0.00 | 8.25 | 1050.00 |
| 100 | 7857.14 | 75 | 0.75 | 11.56 | 1471.27 |
| 100 | 7857.14 | 100 | 1.00 | 22.08 | 2810.18 |
| 100 | 7857.14 | 150 | 1.50 | 28.32 | 3604.36 |
| 150 | 17678.57 | 0 | 0.00 | 14.80 | 837.17 |
| 150 | 17678.57 | 75 | 0.50 | 35.45 | 2005.25 |
| 150 | 17678.57 | 100 | 0.67 | 56.00 | 3167.68 |
| 150 | 17678.57 | 150 | 1.00 | 70.20 | 3970.91 |

Table 1. explains that the additional of partially skirt has the significant effect for increasing the ultimate bearing capacity. Nevertheless, the effect of partially skirt for additional of circular footings is the main issue for this research. From Figure 6. the data observed from the diameter views with different partially skirt lengths, and the result shows that as L/D ratio increases, the ultimate bearing capacity also increased. For example the 75 diameter unskirted circular footings has 735 $kN/m^2$ of ultimate bearing capacity and it has increased the ultimate bearing capacity by 215% when 75 mm partially skirt added, and become 253 % when it is replaced by the 100 mm partially skirt length, it is continuously increased become 369 % when the 150 mm patially skirt length is attached bellow the footings. The best diameter of partially skirted footings on the increament of ultimate bearing capacity is from the 150 mm diameter. The ultimate bearing capacity increment on every diameter of partially skirted footings is served on Table 3.

Table 3. Ultimate bearing capacity increment

| Footings Diameter D (mm) | Partially Skirt Length, L (mm) | Length/Diameter | Max. Load, $P_{max}$ (kN) | Ultimate Bearing Capacity, $q_u$ (kN/m$^2$) | Increment > (%) |
|---|---|---|---|---|---|
| 75 | 0 | 0.00 | 3.25 | 735.35 | - |
| 75 | 75 | 1.00 | 7.00 | 1583.84 | 215 |
| 75 | 100 | 1.33 | 8.21 | 1857.62 | 253 |
| 75 | 150 | 2.00 | 12.00 | 2715.15 | 369 |
| 100 | 0 | 0.00 | 8.25 | 1050.00 | - |
| 100 | 75 | 0.75 | 11.56 | 1471.27 | 140 |
| 100 | 100 | 1.00 | 22.08 | 2810.18 | 268 |
| 100 | 150 | 1.50 | 28.32 | 3604.36 | 343 |
| 150 | 0 | 0.00 | 14.80 | 837.17 | - |
| 150 | 75 | 0.50 | 35.45 | 2005.25 | 240 |
| 150 | 100 | 0.67 | 56.00 | 3167.68 | 378 |
| 150 | 150 | 1.00 | 70.20 | 3970.91 | 474 |

### 3.2 Settlement

To invistigate the settlement of the sand soil as the media and how the effect of adding partially skirt to the settlement, all of the partially skirts and the unskirted circular footings has to be tested. The parameter of the settlement are the load at 2.0 kN by using the chart of load and settlement as the guides (P, kN), Figure 7-9. and the settlement at 10 mm by using the chart of settlement and load as the guides (kN, P), Figure 10-12.

The analysis of settlement on the same value of load (2 kN) is shown on Figure V.7-9. Table 4. gives result of the settlement alteration that caused by different partially skirt length and unskirted on the same diameter of circular footings.

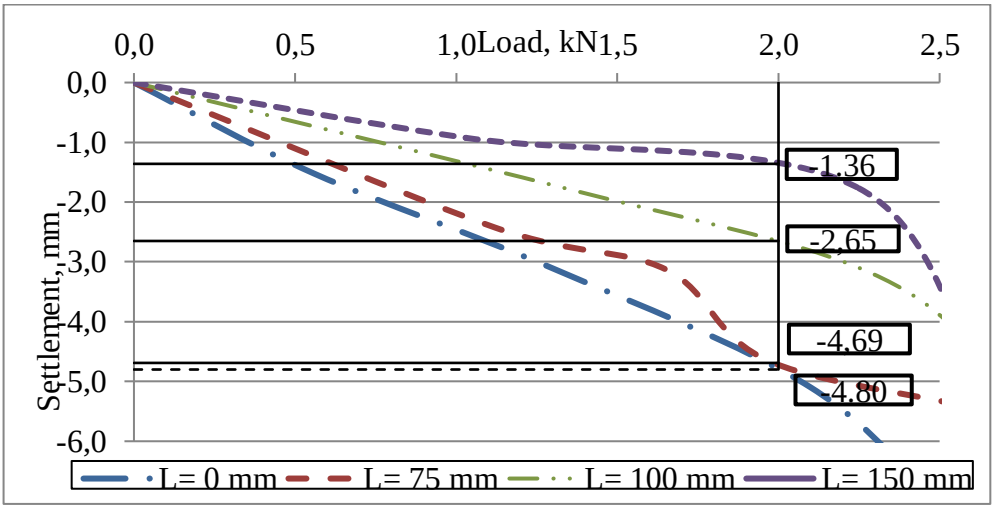


Figure V.6. Settlement analysis on footings diameter 75 mm.

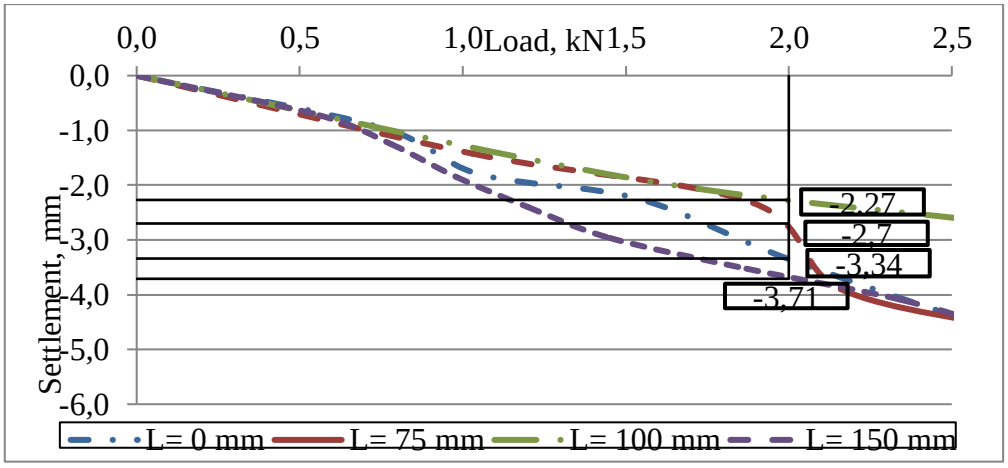


Figure V.7. Settlement analysis on footings diameter 100 mm.

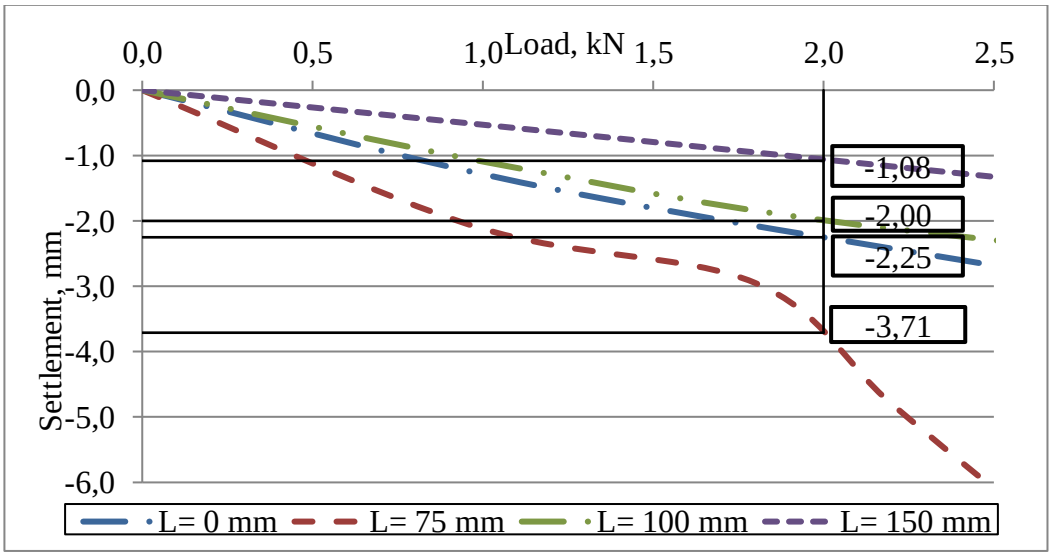


Figure V.8. Settlement analysis on footings diameter 150 mm.

Table V.4. Settlement alteration on 2.00 kN load

| Footings Diameter<br><br>D (mm) | Partially Skirt Length,<br><br>L (mm) | Ultimate Bearing Capacity at P = 2 kN , $q_u$ (kN/m$^2$) | Settlement<br><br>on 2 kN, mm |
|---|---|---|---|
| 75 | 0 | 735,35 | -4,8 |
| 75 | 75 | 1583,84 | -4,69 |
| 75 | 100 | 1857,62 | -2,65 |
| 75 | 150 | 2715,15 | -1,36 |
| 100 | 0 | 1050,00 | -3,34 |
| 100 | 75 | 1471,27 | -2,7 |
| 100 | 100 | 2810,18 | -2,27 |
| 100 | 150 | 3604,36 | -3,71 |
| 150 | 0 | 837,17 | -2,25 |
| 150 | 75 | 2005,25 | -3,71 |
| 150 | 100 | 3167,68 | -2 |
| 150 | 150 | 3970,91 | -1,08 |

The transformation of settlement is caused by the change of partially skirt length and it indicates the partially skirt has the function to reduce the settlement with shaft friction of the buttress of partially skirt. Generally the settlement has decrease when the longer partially skrit added, but the condition is different when 100 mm diameter circular footings attached by 150 mm partially skirt and 150 mm diameter circular footings attached by 75 mm partially skirt.

The minimum settlement happen on 150 mm circular footings diameter with an average setllement of -2.26 mm at 2 kN, while -3.005 mm settlement for the 100 mm diameter circular footings and -3.375 mm settlement for the 75 mm diameter circular footings.

The gap of partially also has a part in reducing the settlement. The 3 mm gap of each on partially skirt can make the settlement reduce for most of the partially skirt.

The analysis of the load on the same settlement of 10 mm is shown on Figure 10-12. Table 5 gives the result of load alteration that caused by the same settlement at 10 mm.

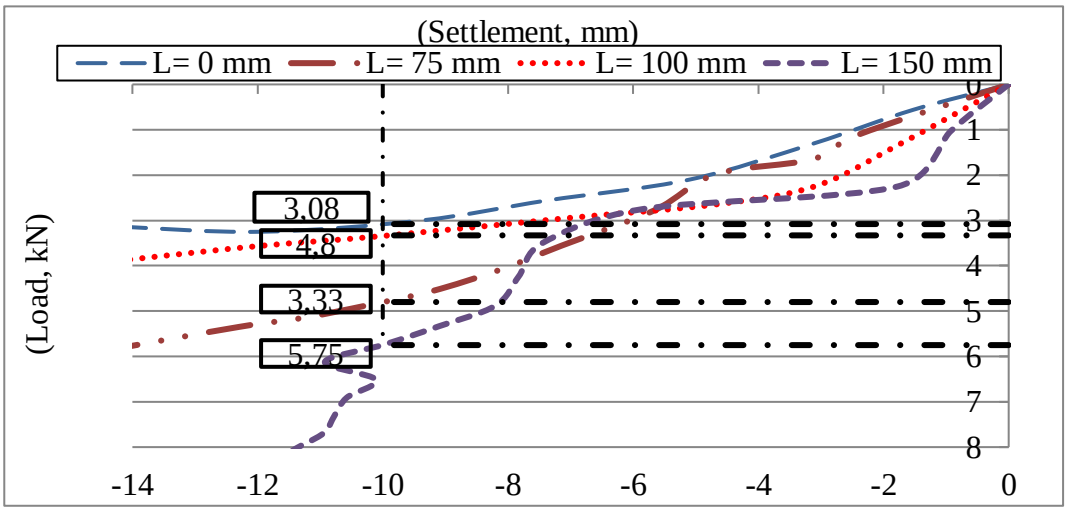


Figure 10. Load analysis at 10 mm settlement on footings diamater 75 mm.

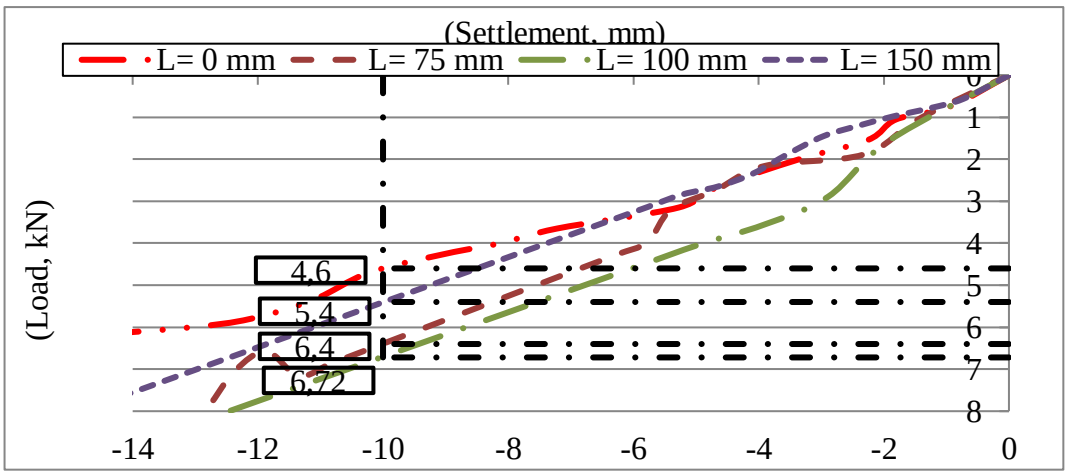


Figure 11. Load analysis on 10 mm settlement of footings diamater 100 mm.

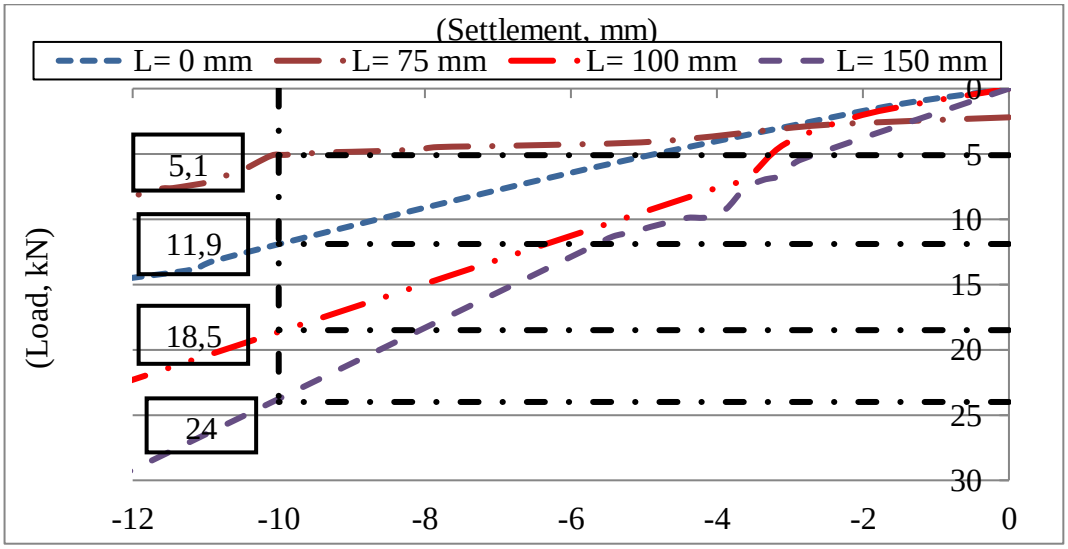


Figure 12. Load analysis on 10 mm settlement of footings diameter 150 mm.

The load that can be hold by partially skirted and unskirted footings. The settlement on 10 mm is a reference to know the load that can be hold by each footings diamater. The partially skirted footings has the ability to hold the load more bigger than the unskirted footings. From the figure, it can concluded that the bigger diamater of partially skirted footings is, the maximum of load it can be hold. For the example is the 150 mm diameter of footings. The 150 mm partially skirt length can hold the load is 24 kN while the unskirted footings can hold 11.9 kN of the load.

## 4. CONCLUSION

Based on research and data analysis discussion, there are some points that the answer of its problem formulation. The answer are :

1. The additional partially skirt on the circular footings is very effective to imrpove the ultimate bearing capacity of circular footings. By the same diameter of circular footings, as the length of partially skirt increases, the ultimate bearing capacity increases.
2. There are two different result for the effect of partially skirt length to footing diameter ratio, L/D. If it is observed on same footings diameter and different partially skirt length, the result shows that the ultimate bearing capacity value tend to increase over the initial value. The other hand, if it is observed by on the same skirt length with different diameter, the result shows ultimate bearing capacity down unstable.
3. The usage of partially skirt on the circular footings is so useful to reduce the settlement. When it is observed by load of 2.00 kN, the data shows that the settlement reduce in large amount of value 82% of average compared to the partially unskirted of circular footings.
4. The partially skirted that is attached in circular footings improve the bearing capacity of circular footings and reduce the impact of settlement, the partially skirted is using less material compared to conventional skirted.

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